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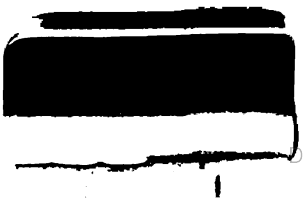

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TANDEM TRUNKING

by

ARTHUR EDWARD VAN HAGAN

A Thesis Submitted for the Degree of

ELECTRICAL ENGINEER

UNIVERSITY OF WISCONSIN

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TANDEM TRUNKING

The object of the following paper is to present a method of handling the calls between telephone offices in the same city located so far apart that it is not economical to establish direct trunk groups between these offices. Before outlining the method under consideration, a brief outline will be given of the conditions that are to be met.

In selecting the location for a telephone office in a small town a development study is made and the office is located at the "wire center". The method of finding the "wire center" is fully explained in text-books on telephony and will not be discussed here.

Each subscriber's line is brought into the office and terminated on an answering jack in front of an operator known as an "A" operator. Enough operators are provided to answer all of the calls that may originate on the lines in that office during the busiest hour of the day.

In order that an "A" operator may complete a call, all of the lines in the office are multipled in front of her provided it is a single office district. It is customary to locate three "A" operators at a section and to multiple all of the lines in each section. This multiple is located above the answering jacks.

Each "A" position is usually equipped with fifteen pairs of cords. The back cord of a pair is plugged into the calling subscriber's answering jack; the connection is

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completed by plugging the front cord into the multiple jack of the called subscriber's line and ringing. Diagram 1 illustrates the completed connection.

The number of lines that can be accommodated in one unit is limited by the multiple capacity. For example, if a unit has capacity for 9600 multiple, a second unit or a new office will be required when this capacity is exceeded.

In large cities the amount of multiple required is greatly in excess of the capacity of a single unit and a number of units are required. The saving in conductors always makes it economical to subdivide the city into districts and to locate an office at the wire center of each district. Even with a number of offices the multiple capacity of a unit is frequently exceeded, and two or more units are often housed together.

In order that connections may be completed between subscribers whose lines fall in different offices, a "B" board is installed in each office and trunk groups are established from each "A" board in the city to each "B" board. Each "B" section, of two positions, has a complete multiple of all the lines in the office up to its capacity. Each "B" position is equipped with a number of trunks terminating on cords and plugs. On receiving an order from an "A" operator for a certain subscriber, the "B" operator plugs one of these trunks into the line called for, the ringing usually being automatic. The number of the trunk

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used is given to the "A" operator, who plugs her connecting cord into the corresponding out-trunk multiple jack.

In a large multi-office district it is customary to omit the subscribers' multiple from the "A" board and to multiple only the outgoing trunks there. The "B" end of the connection is shown by diagram 2.

In passing orders from the "A" board to the "B" board, an order wire is used. This terminates directly on the "B" operator's head set. Each "A" position is equipped with a number of small push buttons or "order wire" keys leading to a "B" position in each unit of the entire exchange district. By depressing one of these keys, the "A" operator establishes connection with the desired "B" operator and passes the order without any preliminaries, providing no other operator is using the circuit. The "B" operator then assigns a trunk to the "A" operator. It will be noticed that communication between the "A" and the "B" operators takes place over the order wire. The "B" operators do not hold any communication with the subscribers.

While the order wire method of operating is in general use in large multi-office districts it has been adopted only because it has been proven superior to what is known as the "ring-down" method of operation. According to the latter method, the "A" operator would plug directly into a trunk to the office desired, automatically setting a signal at the other end. A second operator, known as the "BB" operator,

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would answer and take the order. The length of time that a trunk is held is greater therefore with this method of operating than with call circuit operating, as a certain amount of time is consumed in waiting for the "BB" operator to answer, and a certain amount of time is also used in passing the order over the trunk. It is estimated that the effieciency of ring-down trunks is only 75% of that of order wire trunks. However as an extra pair of conductors is also required for the order wire, the order wire trunks show no saving until more than five trunks are required. A trunk efficiency curve showing the number of trunks required to handle various numbers of calls is given in Appendix A.

A new condition was presented in Chicago when the telephone company was granted the franchise of December, 1907. Up to the time this ordinance was granted there was a minimum toll charge of 10 cents a call between the offices comprising the Chicago Exchange area and certain offices near the outskirts of the city. Under the new ordinance the toll rate was abolished. The outlying offices affected were Austin, Irving Park, Rogers Park, South Chicago, and West Pullman, all of these being common battery offices. In addition to these there were a number of small magneto offices shown in diagram C. These offices were known as neighborhood offices.

The subscribers in the neighborhood offices were given the choice of two sets of rates:

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One set entitled them to free service with all other subscribers whose lines terminated in that office, but necessitated a five cent charge on calls to other offices. The second set was that prevailing throughout the city.

A careful estimate was made of the calls per busy hour that would pass each way between each neighborhood office and every other office in the city. An estimate is given in Appendix B of the number of calls at the end of the year 1910. This estimate is the basis of the trunk estimate that follows later in the report, and a brief statement of the method of preparing this table is therefore of importance. Several other methods were studied carefully before this method was adopted.

It is well known that if the calls originating in an office in the busy hour be divided by the number of stations in that office, the quotient is approximately constant. The same statement applies to the calls incoming to an office. Therefore if the number of calls passing from one office to another be divided by the product of the stations in the two offices considered and the square root extracted, the value obtained will be a constant for that pair of offices. If this constant be multiplied by the square root of the product of the stations estimated for these two offices for some future date, the product is the number of calls per busy hour from one to the other. This is illustrated in Appendix C.

It was found that the above mentioned constant is smaller

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for two residence offices than for a residence and a business office; also that the constants become smaller as the distance between offices increases. Two curves were plotted with distance as abscissae and the various values of the constants as ordinates, one curve being for pairs of business and residence offices, and the other for pairs of residence offices. The data for these curves was obtained by determining the value of the constant for each pair of the sixteen offices in what was then the Chicago Exchange district, there being 240 pairs of offices. The value of the constant in each case was determined after a study of its monthly fluctuation for six years.

Knowing the distance from each of the offices in the Chicago Exchange to the offices that were brought into the Chicago Exchange under the new ordinance, the constant was obtained from the curve in order to determine the traffic between each new office and each of the offices in the old Chicago Exchange district. These constants together with the station estimate referred to previously gave data sufficient to determine the number of calls per busy hour between each pair of offices in the Chicago Exchange limits. A statement of this traffic is given in Appendix B.

TRANSMISSION DATA AND TRUNK COSTS.

It is customary to provide two conductors for each trunk thus giving a metallic circuit. The gauge of wire necessary

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for various distances together with the cost per cable pair per mile is furnished in Appendix D. Knowing the distance between two offices and the number of trunks, the cost of the trunks is readily determined. Appendix E gives the distance between each pair of offices comprising the Chicago Exchange.

From the information given above it is readily seen that if an attempt was made to provide direct call circuit trunks both ways between each pair of metropolitan and neighborhood offices, the expense would be enormous. It is also obvious that the reason for this expense is that the traffic between distant pairs of offices is light and that only a few trunks would be required for each group. From Appendix A it appears that the efficiency of the trunk groups decreases when the number of trunks per group decreases. These long trunks are high grade necessarily for transmission reasons and consequently are more expensive than short trunks. The expense of direct trunks for long haul business is brought out later in the study.

With a view to handling the long haul traffic in the most economical manner, a study has been made of the several possible plans of operation. The operating features of these plans will now be outlined together with a brief statement of their advantages and disadvantages. The costs and relative rankings of the plans is also given in this outline, the cost figures being given in detail in Appendix F and Appendix H,

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plans 1 to 10.

In order to simplify the discussion of the various plans, it was assumed as a typical long haul call that Edgewater 4123 was calling West Pullman 2184, the call being relayed at Main office. It will be seen from diagram 5 that Main office serves as a natural relay point for calls from the south side to the north and west side neighborhood offices, and also for the calls from the west or the north side offices to the neighborhood offices on the south side.

In discussing each of the following plans it is assumed that the plan is actually in operation. It should also be stated that the cost figures shown in the attached tables are only a fraction of the total cost involved. However for the purpose of comparison of the relative costs of the various plans these figures are as satisfactory as the complete cost figures, while the discussion is very much simplified.

The term "TANDEM TRUNKING" applies to the method of operating that requires a "RELAY" or "TANDEM" operator between the calling office and the called office to complete the connection. The name is derived from the fact that the trunk from the metropolitan office to the relay board is in tandem with the trunk from the tandem board to the neighborhood office.

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PLAN 1: CALL CIRCUIT TO RELAY OPERATOR.
CALL CIRCUIT TO WEST PULLMAN.

There is a special group of trunks from Edgewater to the relay board at Main, terminating in cords and plugs. The Edgewater "A" operator, on receiving a call for West Pullman, comes on a call circuit to the relay operator and says "Edgewater, West Pullman 2184." The relay operator assigns a trunk to her saying, for example, "32". She then cuts off from her incoming order wire, comes in on the West Pullman order wire and says "Main, 2184". The West Pullman "B" operator assigns a Main trunk to her and completes the connection. The prefix "Main" will, of course, be used only on bunched order wires.

The relay operators work in teams of not more than two, a larger group being impossible as all the operators could not reach all the trunks. Only one operator is on the circuit at a time. When she cuts off the circuit, a tone is put on automatically, indicating to the "A" operators that there is no relay operator on the circuit. At the same time a lamp lights indicating to the other relay operator of the team that she is to come in on the circuit in order to be ready for the next call.

Instead of using the trunks which terminate at the Main office "B" board, it seemed more desirable to start another group of trunks although the circuit efficiency was lower. It was thought that the flashing of the lamps would

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interfere with the "B" operator's work, if the same group of incoming trunks was used by the relay operators. Then, too, the transmission requirements of the relay trunks are higher than for the regular inter-office trunks.

The cost and ranking of this plan as compared with the other nine plans considered is as follows:

	Cost	Rank
Investment	$38,907.00	3
Annual cost	9,439.00	5

ADVANTAGES:

(1) The subscriber has to give his order only once.

(2) The plan is reversible; that is it applies equally well to a call in either direction.

DISADVANTAGES:

(1) The Edgewater "A" operator must pass two prefixes and one subscriber's number until the traffic warrants an individual Edgewater circuit to the relay board at which time the prefix "Edgewater" might be omitted. The extra prefix causes a slight drag reducing her load. The load is given in Appendix G. As the drag referred to will reduce her load only one-half of one percent it has been neglected.

(2) The relay operator must handle three prefixes, two trunk numbers, and one subscribers number. This necessitates special training of the operators who handle these calls. On the other hand, the special work is put on special operators rather than on the "A" operators, as it is easier to train

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a few operators than to train all the "A" operators in the city.

(3) Owing to the fact that the trunks from the city offices terminate on plugs, not more than two relay operators can work in one team because they could not reach the trunks.

(4) The teams are limited to two operators and there is more likelihood that both operators would be busy off the circuit than if larger teams were used.

(5) The force of relay operators cannot be decreased more than 50% as the business lightens without a change in the system because there must always be enough operators to reach the incoming trunks.

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PLAN 2: CALL CIRCUIT TO RELAY OPERATOR.

CALL CIRCUIT TO WEST PULLMAN.

Instead of terminating the incoming trunks in plugs, as is done in plan 1, they are terminated in multiple jacks in front of all the relay operators, and are equipped with magnetic busy signals. The several incoming call circuits are multipled in front of all the relay operators and each operator has a key for each order wire.

There are two lamps in each position associated with each order wire. One of these, when it is lit, indicates that there is no relay operator on the incoming circuit. The first idle operator then cuts in and is ready for the next order.

When there is no relay operator on an order wire, a tone is automatically thrown on it to indicate this to the "A" operators.

In case there is an extreme rush of business, several incoming order wires might be vacant at the same time and it may happen that an "A" operator is waiting on one of the vacant order wires to give a call. The second lamp on the order wire is provided to meet this condition. It lights only when an "A" operator takes a circuit that is not covered by a relay operator. The first idle relay operator then answers on this circuit.

The second lamp is also of assistance in light hours when the number of relay operators is less than the number

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of incoming order wires. The number of relay operators may be decreased with the traffic until there is only one.

ADVANTAGES:

(1) This plan is the most economical of those considered from the standpoint of initial and of annual costs. These costs, together with the rank of this plan, are as follows:

	COST	RANK
Investment	$38,311.00	1
Annual Cost	8,789.00	1

(2) As the teams are larger, there is less likelihood that an "A" operator will be delayed while waiting for a relay operator to come on the circuit.

(3) The system is flexible and can be applied equally well to traffic in the reverse direction, the same relay operators being used.

(4) The plan is among the most rapid of those considered, the additional time required to complete a call being that required by the relay operator to cut off her order wire, come in on a West Pullman order wire, ask for the desired subscriber, and plug in.

DISADVANTAGES:

(1) The Edgewater "A" operator must pass more information than on her regular city calls as stated under plan 1, disadvantage 1.

(2) The relay operator must handle three prefixes, two

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trunk numbers, and one subscribers number. Her work is, therefore, more complicated than either "A" or "B" work, requiring special training as stated under plan 1, disadvantage 2.

(3) The work of the relay operator is increased slightly over plan 1, as she has to handle two cords in completing a connection instead of one. She also has to look over her groups of incoming trunks first to find the proper group before assigning a trunk to an "A" operator.

(4) There is the possibility that a second order may be given over the call circuit to the relay operator while she is locating the desired group of trunks and searching for an idle trunk. However, with the groups plainly marked and with magnetic busy signals there should be little difficulty on this account, especially as the prefix of the calling office is given first.

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PLAN 3: CALL CIRCUIT TO RELAY OPERATOR AND BACK.
CALL CIRCUIT TO WEST PULLMAN.

The Edgewater "A" operator takes the order, tells the subscriber to hang up, comes in on a call circuit to the relay operator, and says "Edgewater 4123" (the calling number). The relay operator cuts off the order wire, comes in on an order wire to the Edgewater "B" operator, and orders up 4123. The relay operator then asks the calling subscriber for his order, comes in on a West Pullman order wire, and says "Main, 2184". The West Pullman operator then assigns a Main trunk to her and completes the connection.

The arrangement of order wires for the relay operators is the same as under plan 2.

ADVANTAGES:

(1) As any relay operator can handle any call, in or out, the number of operators required during the light hours is regulated by the traffic instead of by the number of positions that must be manned, giving a high operator's efficiency during the light hours. The operators load, however, is very low on account of the complicated work.

(2) No special group of trunks is required between Edgewater and the relay board, as the regular city trunks from Main to Edgewater are to be used for traffic both ways.

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DISADVANTAGES:

(1) The calling subscriber is asked twice for his order.

(2) The calling subscriber has to hang up.

(3) On calls from nickel phones, it will be necessary for the "A" operator to instruct the relay operator to collect the nickel, as the "A" operator will be off the connection. No decrease has been made in the "A" operators load for this, as the proper allowance is problematical.

(4) The city trunks are designed to give satisfactory transmission between each pair of offices, but they should not be used for relaying calls to points beyond because of a loss in transmission. In some cases this may be of no consequence; in others it would be almost impossible to talk. This plan then would be limited to those offices where satisfactory transmission could be obtained over the city trunks.

The objections to this plan are enough to condemn it, and cost figures have not been prepared for it.

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PLAN 4: CALL CIRCUIT TO RELAY BOARD.
RING DOWN TO WEST PULLMAN.

The Edgewater "A" operator comes in on a call circuit to a relay operator and says "Edgewater, West Pullman." A Main trunk is assigned to her and the relay operator completes the connection to a ring-down trunk to West Pullman. The West Pullman "BB" operator the asks the calling subscriber for his order, and completes the connection.

ADVANTAGES:

(1) Less work is required of the Edgewater "A" operator and of the relay operator than in the other plans considered. No work is required of the Edgewater "B" operator.

(2) The relay operator does not cut off the incoming order wire at any time.

DISADVANTAGES:

(1) The ring-down trunks to West Pullman are only 75% as efficient as call circuit trunks would be. This plan is, therefore, among the most expensive.

(2) The traffic is double tracked, making the trunk efficiencies lower than under plan 3.

(3) It is necessary for the subscriber to give the number twice.

	COST	RANK
Investment	$43,161.00	6
Annual cost	9,383.00	4

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PLAN 5: CALL CIRCUIT TO RELAY BOARD AND BACK. RING DOWN TO WEST PULLMAN.

The Edgewater "A" operator takes the subscribers order, tells him to hang up, and disconnects. She then comes in on a call circuit to the relay board and says "Edgewater 4123, West Pullman." The relay operator cuts off the order wire, thereby giving the next operator a signal to take it, comes in on a circuit to the Edgewater "B" operator, and orders up Edgewater 4123. She takes the trunk assigned and completes the connection with a ring-down trunk to West Pullman. The West Pullman "BB" operator asks the Edgewater subscriber for his order and completes the connection.

ADVANTAGES:

(1) There is an increased circuit efficiency between Main and Edgewater, as the regular Main-Edgewater trunks are used.

(2) The number of relay operators is governed by the traffic, allowing of a more efficient use of operators during light hours.

DISADVANTAGES:

(1) There is more reaction on the "A" operator, as she has to pass two prefixes and the subscribers number.

(2) The subscriber must give his order twice.

(3) The double tracking of the West Pullman business and the use of ring-down trunks cuts down the circuit efficiency and increases the expense.

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(4) Difficulty in collecting the nickel from nickel telephones as explained in plan 3, disadvantage 3.

(5) Transmission difficulties on account of using inter-office trunks for relaying calls as explained under plan 3, disadvantage 4.

No cost figures have been prepared on this plan as it's disadvantages are sufficient to eliminate it from further consideration.

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PLAN6: RING DOWN TO RELAY BOARD.
CALL CIRCUIT TO WEST PULLMAN.

Edgewater connects to an Edgewater-Main trunk and sets a signal in front of a number of operators at the relay board. The subscriber repeats his order to the relay operator who completes the connection to West Pullman over a call circuit trunk in the regular manner.

ADVANTAGES:

(1) The reaction on the Edgewater "A" operators is a minimum and no work is required from the Edgewater "B" operators.

(2) The relay operators are worked at a maximum efficiency.

(3) The efficiency of the West Pullman trunks is a maximum.

DISADVANTAGES:

(1) The ring-down trunks to the relay board have a lower efficiency than call circuit trunks.

(2) The subscriber must repeat his order twice.

	COST	RANK
Investment	$38,504.00	2
Annual cost	8,821.00	2

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PLAN 8: DIRECT CALL CIRCUIT TRUNKS FROM EDGEWATER TO WEST PULLMAN.

The Edgewater "A" operator will pass the call to a "B" operator at West Pullman just as is done on any inter-office call. This plan is evidently the most desirable from an operating standpoint and it is intended to install direct call circuit trunks wherever they prove in. These figures were prepared to see whether the plan was applicable to the entire city.

ADVANTAGES:

(1) Double handling of the traffic is eliminated. This decreases the chances for error and increases the speed of completing the connection.

DISADVANTAGES:

(1) There would probably be considerable expense involved in bringing the transmission up to standard on the long call circuits where a number of offices used the same circuit to West Pullman.

(2) This plan cannot be applied in the reverse direction as it is out of the question to provide direct call circuits between each neighborhood office and each metropolitan office for double track service. It is, therefore, necessary to relay a large part of the business into the city in any event.

	COST	RANK
Investment	$59,713.00	7
Annual cost	10,398.00	7

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PLAN 9 : CALL CIRCUITS TO WEST PULLMAN AND TO MAIN.

Edgewater comes in on a call circuit to West Pullman, says "Main 2184;" and a Main-West Pullman trunk is assigned to her, for example "32". She then comes in on a call circuit to a Main "B" operator, says "West Pullman 32," and an Edgewater-Main trunk is assigned to her, the Main "B" operator connecting this trunk to West Pullman trunk #32.

ADVANTAGES:

(1) The subscriber is not asked for his order a second time.

DISADVANTAGES:

(1) Each of the calls for neighborhood exchange subscribers require almost double the work from the Edgewater "A" operator that the ordinary call requires.

(2) The work of the "A" operator on these calls tends to cause a drag in her work and thus reduce her load.

(3) There would probably be considerable expense involved in bringing the transmission up to standard on the long bunched call circuits and it is very doubtful if the transmission could be kept up to grade as the offices are re-grouped from time to time without a great deal of study and special attention.

	COST	RANK
Investment	$39,439.00	5
Annual cost	9,662.00	6

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PLAN 10: CALL CIRCUIT TO MAIN OFFICE "B" BOARD.
CALL CIRCUIT TO WEST PULLMAN.

The Edgewater "A" operator, on receiving a call for West Pullman, goes in on the regular Main call circuit and says, "Edgewater, West Pullman 2184." The Main "B" operator assigns a trunk to her, saying for example "32." The Main "B" operator then cuts off from the incoming order wire, goes in on the West Pullman order wire, and says "Main, 2184." The West Pullman "B" operator assigns a Main trunk to her and completes the connection. The prefixes Edgewater and Main will of course be used only on a bunched order wire.

When the "B" operator cuts off from the incoming order wire, a tone will automatically be thrown on the circuit, thus indicating to the"A" operators that there is no "B" operator on that circuit.

Two groups of trunks from Edgewater to Main would be necessary, one of these consisting of low grade trunks and the other of high grade trunks. The former would be used only for calls from Edgewater to Main subscribers while the latter would be used in tandem with the neighborhood trunks on calls where Main served as a relay point. The total number of Edgewater-Main trunks, both high and low grade, would be determined by the total number of calls from Edgewater to Main including the calls completed over trunks in tandem. The number of high grade, or tandem, trunks would be determined by the number of relayed calls.

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The high grade trunks would be used on Edgewater-Main calls only when all the low grade trunks were in use.

	COST	RANK
Investment	$39,316.00	4
Annual cost	9,081.00	3

ADVANTAGES:

(1) The subscriber gives his order only once.

(2) A separate relay board is not necessary. This plan is therefore of especial use where there is not enough traffic to warrant a separate relay board and it may be employed to good advantage in the outlying metropolitan offices like Hyde Park and Wentworth.

DISADVANTAGES:

(1) The principal objection to this plan is the drag introduced in the "B" operators work, necessitating a reduction in the load. The drag would be especially bad at Main for it would affect all the "B" operators and would apply on sixteen percent of the calls incoming to the Main "B" board. At Wentworth, the heaviest relay point outside of Main, only nine percent of the calls from the south side offices to Wentworth would be affected. There would be no calls from the north and the west side offices passing through the Wentworth "B" board for neighborhood offices beyond Wentworth as Main office would relay these calls. The drag on the "B" operators would therefore be less serious

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at Wentworth and the other outlying tandem centers than at Main office.

The time required from a "B" operator on a relayed call would be at least double that required for the ordinary call. The extra time required on the relayed calls would tend to cause a reduction in the "B" operators load on her inter-office calls as the working time is not uniform. This reduction has not been made and the plan has therefore been favored in a measure so far as the actual cost figures are concerned. As it does not prove in, a closer analysis is unnecessary.

(2) The "B" operators must deal with three prefixes, two trunk numbers, and one subscribers number on each call for a neighborhood office. As this work is required only on part of the calls handled by the "B" operators, a larger percentage errors would result than if the work was specialized.

(3) In assigning trunks, the Main "B" operator must distinguish between calls for Main subscribers and calls for neighborhood subscribers, assigning low grade trunks on the first class of calls and high grade trunks on the second class.

(4) It would be exceedingly difficult to arrange for the installation of out-trunk multiple enough in the "B" board to handle calls in both directions as outlined in

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plan 10. While calls from the metropolitan offices to the neighborhood offices might be handled according to this plan, it would be necessary to handle calls in the reverse direction in some other manner.

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#The operating objections to plans 3, 5, and 7 were sufficient to condemn them as stated in the "DISCUSSION" on the following pages.

The cost figures given above are taken from the detail sheets in Appendix H.

	West Pull. calling subscriber hangs up and is called back.	------	-	-----	-
6.	R.D. to relay board.C.C. to West Pull.	38,504.	2	8,821.	2
#7.	R.D. to relay board. R.D. to West Pull.	-------	-	-----	-
8.	Direct C.C. trunks from Edgewater and other city offices to West Pullman.	59,713.	7	10,398.	7
9.	C.C. to West Pull. & to Main. Main "B" opr. connects an Edgewater-Main trunk to a Main-West Pullman trunk.	39,439.	5	9,662.	6
10.	C.C. to Main "B" board. C.C. to West Pullman.	39,316.	4	9,081.	3

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RANKING OF PLANS ACCORDING TO COST.

PLAN		INITIAL COST	RANK	ANNUAL COST	RANK
1.	C.C. to relay board. C.C. to West Pull. Trunks end in plugs at relay board.	$38,907.	3	$9,439.	5
2.	C.C. to relay board. C.C.to West Pull. Trunks end in multiple jacks with mag. busy sigs. at relay board.	38,311.	1	8,789.	1
#3.	C.C.to relay board and back.C.C. to West Pull. Calling subscriber hangs up and is called back.	--------	-	-----	-
4.	C.C. to relay board. R.D. to West Pull. Trunks end in plugs at relay board.	43,161.	6	9,381.	4
#5.	C.C. to relay board & back. R.D. to West Pull. Calling subscriber hangs up and is called back.	------	-	-----	-
6.	R.D. to relay board.C.C. to West Pull.	38,504.	2	8,821.	2
#7.	R.D. to relay board. R.D. to West Pull.	-------	-	-----	-
8.	Direct C.C. trunks from Edgewater and other city offices to West Pullman.	59,713.	7	10,398.	7
9.	C.C. to West Pull. & to Main. Main "B" opr. connects an Edgewater-Main trunk to a Main-West Pullman trunk.	39,439.	5	9,662.	6
10.	C.C. to Main "B" board. C.C. to West Pullman.	39,316.	4	9,081.	3

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DISCUSSION OF PLANS:

In summarizing, plans 3 and 5 are eliminated because of the fact that they are undesirable from the subscriber's standpoint and because of transmission and operating difficulties. It is obviously out of the question to make all the city trunks of sufficiently high grade to give satisfactory transmission on the neighborhood calls. It might be possible to split the groups of trunks, using one for calls that were relayed and one for local calls, but this plan would introduce another prefix and would reduce the "B" load. Furthermore, the apparent saving disappears when satisfactory transmission is assured.

Plan 7 was merely mentioned as a possible plan but was considered too undesirable for further attention on account of the expense of the ring-down trunks and the necessity of passing the order several times over ring-down trunks. An additional objection is that this plan requires more time for the completion of a call than any of the others considered with the possible exception of plans 3 and 5.

Plan 4 is objectionable because of the expense and also because a system involving ring-down operation is slower than one involving only call circuit operation. Then too it is not so satisfactory from the subscribers standpoint as he must give his order twice, unless the "A"

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operator stays in on the ring-down trunk and passes the order. This plan has therefore been eliminated.

Plan 8 will be followed wherever direct call circuits prove in but it is, of course, out of the question to furnish direct call circuits between every pair of offices inside the city limits. Only the calls from the metropolitan offices to one neighborhood office have been considered in the study and this plan has proven to be decidedly more expensive than any of the others.

Plans 9 and 10 are eliminated from further consideration, partly because of their cost and partly because of the drag that the relayed calls would place upon the "B" operators. A material reduction should be made in the "B" loads in order that the service should not be degraded. If this reduction were made, the cost of these two plans would be increased correspondingly and they would appear in an even less favorable light.

Plan 1 is rejected because it does not embody so many operating advantages as plan 2 while it is more expensive.

Plans 2 and 6 are left for final consideration. Plan 2 has the advantage from the cost standpoint. From a service standpoint plan 2 has two advantages which are of even greater importance.

(a) The time required to complete a call is less.

(b) It is unnecessary for the subscriber to give his

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order twice.

PLAN 2: OPERATION OF CIRCUITS.

Before making the recommendation, a brief discussion of the circuits is essential to a clear understanding of the method of operation outlined in plan 2.

Diagram 4-A shows the order wire circuits involved in establishing a connection through the tandem board. The order wire circuit to the left is used from the "A" board to the tandem board. The one to the right is the regular inter-office order wire, the tandem operator cutting in on the order wire to the desired "B" board by depressing the key shown.

The operation of the order wire incoming to the tandem board is the special feature of this plan. Instead of terminating each incoming order wire on the head set of a particular operator, the incoming order wires are multiplied through all the tandem positions. In each position a key and two lamps are associated with each order wire.

During the busy part of the day, a tandem operator is listening on each order wire; i.e., her key is thrown so that her set is cut across the order wire and neither of the lamps associated with this order wire can light.

When an "A" operator passes a call to a tandem operator, the latter cuts off from the order wire by throwing her key to the normal position. The white lamp associated with this

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order wire then lights in every tandem position and the first idle operator takes the circuit.

In case several circuits are vacated at the same time and an "A" operator comes in on one of them, it is desirable to indicate this condition to the first idle tandem operator so that the service may be as prompt as possible. When this condition obtains, the red lamp lights.

Whenever an order wire is not covered by a tandem operator, this fact is indicated to the "A" operators by a tone that is placed on the circuit. It will be noticed that the tone is cut off the circuit when one of the tandem operators answers. It will also be noticed that if two operators should answer on the same circuit at the same time, one of them will be cut off as soon as the other throws her key. It is therefore impossible to have any confusion on the order wire due to two tandem operators attempting to take the same order.

A switch is provided to cut the white lamps out of service during the light hours when the number of tandem operators is less than the number of incoming order wires. The red lamp operates, just as it does during the day, when an "A" operator comes in on a circuit to give an order. As the "A" operator must always wait for a tandem operator to answer her during these hours, the service is a little slower than during the day but this is of little consequence in

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the light hours as the loads are low.

Diagram 4-B illustrates a connection completed through the tandem board. It will be noted that the circuits have been arranged so that the "A" operator will have supervision over both the calling and the called subscribers just as on a regular "A"-"B" connection. It will also be noticed that the ringing will not start until the "A" operator has taken the proper trunk to the tandem board and the tandem operator has taken the proper trunk to the "B" board. This minimizes the seriousness of errors on the part of the "A" or the tandem operators.

A guard lamp is installed on each trunk in the end position at the tandem board so that, if an "A" operator misplugs, the call may be answered promptly by the supervisor at the tandem board and cared for properly.

Each trunk is equipped with magnetic busy signals throughout the tandem board in order to guide the tandem operators in assigning trunks. As soon as a tandem operator receives an order, she plugs the back cord of a pair of cords into an idle trunk from the calling office, thus setting the busy signal on this trunk throughout the tandem board. She then assigns this trunk to the calling "A" operator as already explained.

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RECOMMENDATION:

Inasmuch as plan 2 provides an accurate, rapid, and economical method of trunking the calls to and from the neighborhood offices where direct trunks do not prove in, it is recommended that this method of operating be employed.

About fourteen tandem operators would be required at Main office to handle this traffic. This is sufficient to warrant the installation of a separate board and it is recommended that this be installed.

At the outlying tandem centers it is recommended that one or two idle "A" positions be converted temporarily to tandem positions and used until such a time as a separate tandem board proves in.

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APPENDICES

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DRAWINGS

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Diagram 2

A "B" POSITION

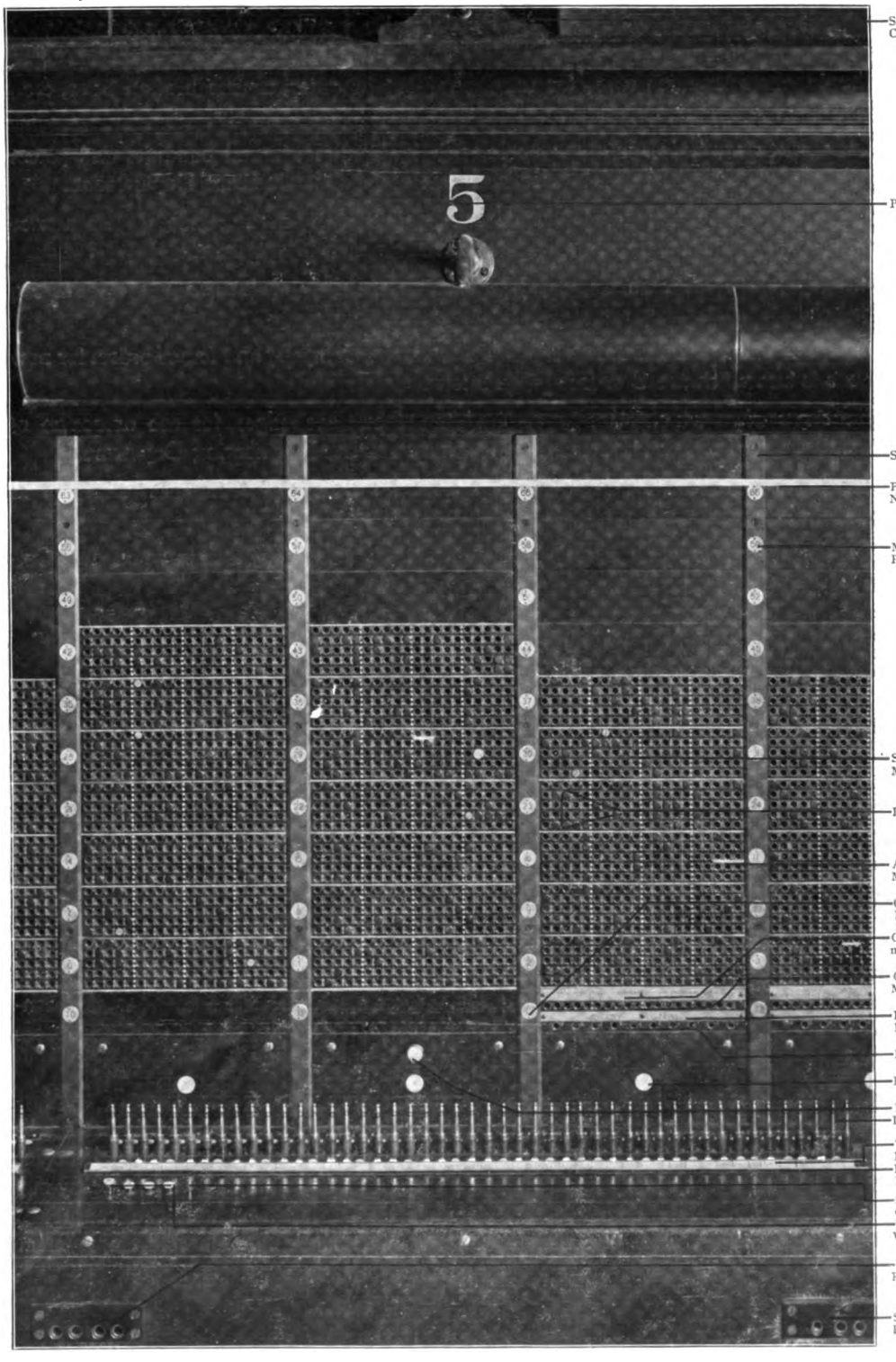

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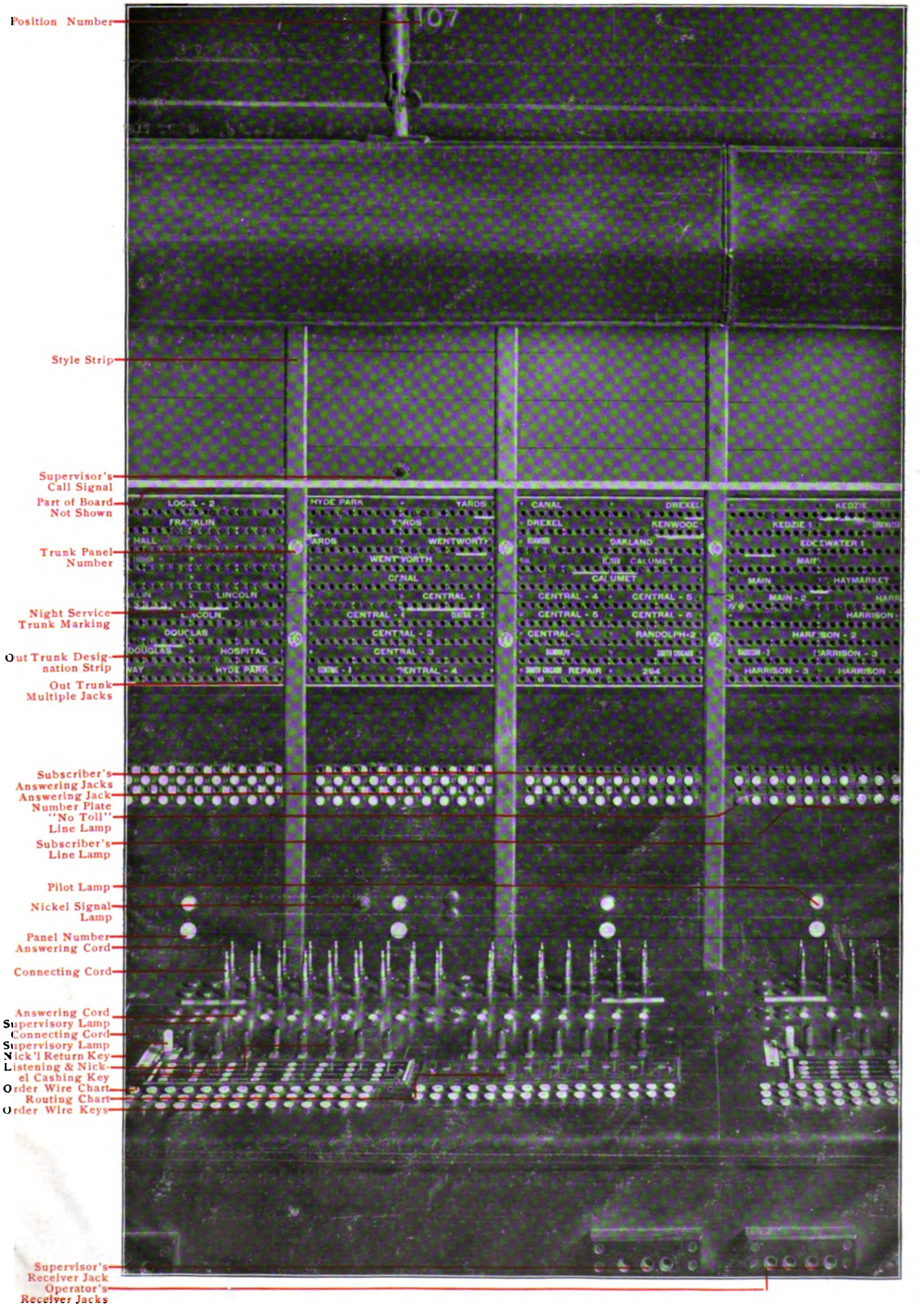
Diagram 1

AN "A" POSITION



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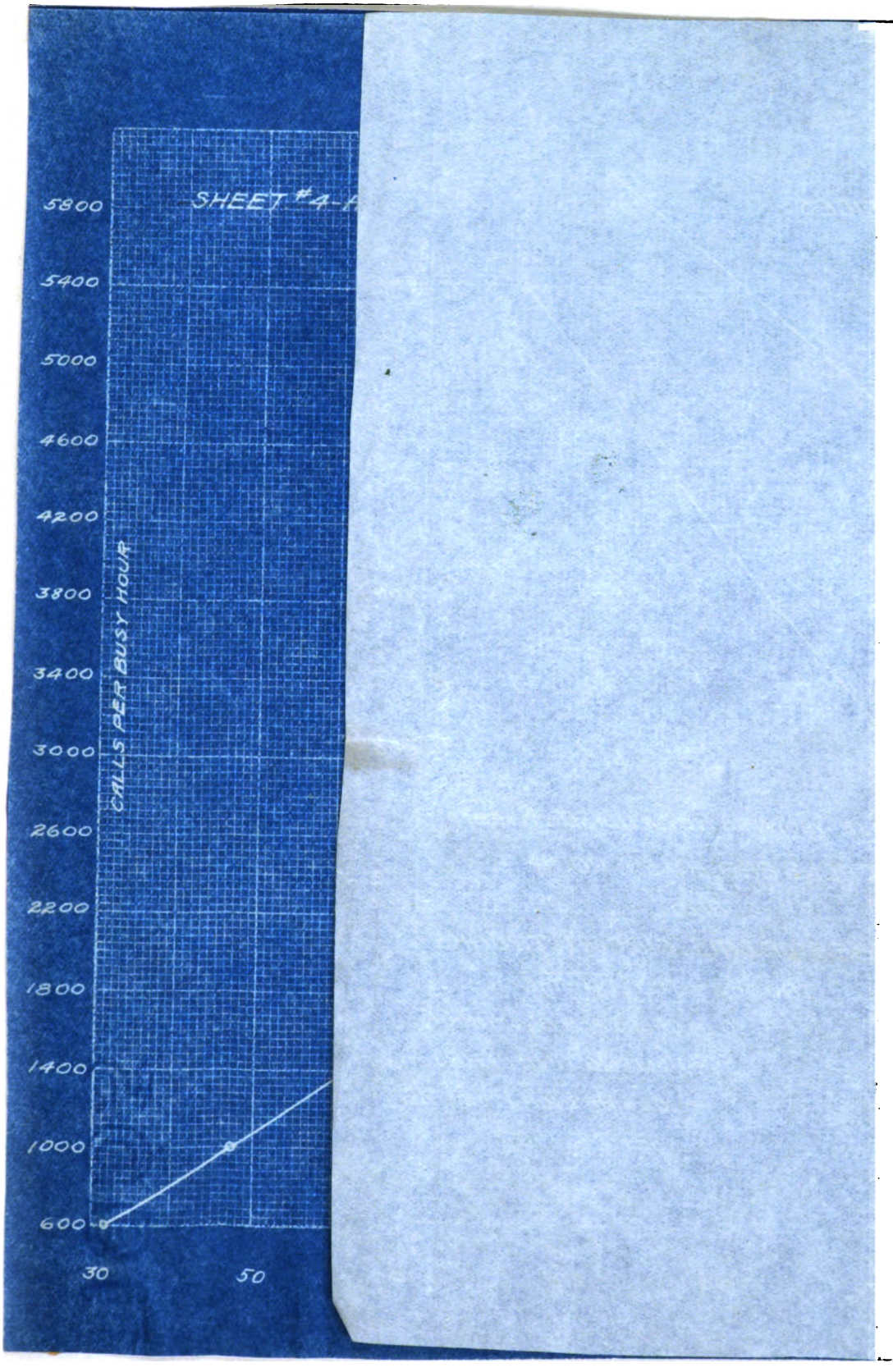

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APPENDIX C:

Derivation of formula used in determining the number of calls trunked from one city office to another during the busy hour.

Let S_x = present stations in office X.

" S_y = " " " " Y.

" C = " calls per busy hour from X to Y.

" S'_x = estimated stations in office X at a future date.

" S'_y = " " " " Y " same "

Then to find the estimated number of calls per busy hour (C') at that time, the following relation is obviously true.

$$(C')^2 = \frac{S'_x}{S_x} C \cdot \frac{S'_y}{S_y} C$$

$$C' = \frac{C}{\sqrt{S_x \cdot S_y}} \sqrt{S'_x \cdot S'_y}$$

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APPENDIX D: TRANSMISSION DATA AND TRUNK COSTS.

The grade of cable conductors to be used for the various trunks is readily determined from the following table when the distance between the offices is known. These distances are given in Appendix E.

The initial and the annual cost per cable pair per mile is also shown.

UP TO MILES	USE GAUGE	Cost per Mile. INVESTMENT	ANNUAL COST
4.76	22	$11.38	$1.30
7.13	19	20.59	2.36
9.24	#22L	25.92	3.74
15.93	#19L	34.34	4.70
27.95	#16L	53.35	6.89
For greater distances	#13L	87.50	10.81

Loaded cable.

In determining the gauge of cable to be used, each trunk to the relay board must be of sufficiently high grade to give standard transmission when connected to the longest trunk from that board. For example the distance from Edgewater to West Pullman necessitates the use of 16L conductors for the trunks from Edgewater to the tandem board.

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APPENDIX F: COST OF CABLE CONDUCTORS.

In some of the following plans the regular group of Edgewater-Wentworth (or Edgewater-Main) trunks is combined with the group of high grade trunks to be used on calls to neighborhood offices. The Wentworth "B" operator would be instructed to use the high grade trunks on calls to Wentworth subscribers only in case all the low grade trunks are busy.

An illustration of the method of figuring the cable cost and switchboard trunk cost is as follows:

Suppose that Edgewater-Wentworth calls required 10 trunks, 19L

-West Pull. 4 16L

combined calls 12

Of the 12 trunks, there would then be 4--16L.

and 8--19L.

In figuring cable costs, the saving on 2--19L trunks from Edgewater to Wentworth would be credited against the cost of 4--16L trunks.

Terminal equipment on 2 extra trunks only would be charged for.

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Appendix F. PLANS 1 & 2.

Direct C.C. trunks from Main, Central, Harrison, and Wentworth to West Pullman. Main relays for points north and west; Wentworth for others. Relay trunks at Main and Wentworhh to terminate at special relay board.

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APPENDIX F. PLAN 4.

Direct R.D. trunks from Main, Central, Harrison and Wentworth to West Pullman. Main relays for points north and west. Wentworth for others. C.C. trunks end in plugs at relay board.

	Mi.to W.Pull.	Total Calls B.H.	Calls B.H.	Total Trks	Ckt.Mi.	Mi.

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APPENDIX F. PLAN 6.

Direct C.C. trunks to West Pullman from Main, Central, Harrison and Wentworth. Main relays for points north and west; Wentworth for points south of Main. Incoming trunks to relay board are ring-down and are multipled in front of relay operator.

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APPENDIX F. PLAN 8.

Direct Call Circuit trunks to West Pullman from all Metropolitan Offices.

Over C.C. #1 to W.Pull.	Mi. to W.Pull.	Calls B. H. to W.Pull.	Trks.	Ckt.Mi. of Trks.	Gauge	Mi. of	Gauge

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APPENDIX F. PLAN 9.

C. C. to West Pullman and C. C. to Relay Point.

Over C.C. #1 to W.Pull.	Mi.to W.Pull. or Relay Office	Total Calls B. H. through Relay	Calls B. H. to W.Pull.	Total Trks. to Relay	Ckt.Mi. W.Pull. Trks.	Ckt.Mi. of Gauge Trks.	Mi. of C.C.	Gauge

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APPENDIX F.

CREDIT PLAN 10.

Over C.C.#1.	Total Calls to Relay Pt.	Calls to Main or Wentwth.	Relayed Calls	Common Group Total Trks	Separate Group Ww.or Main Trks.	Separate Group Relay Trks	W.Pull. Trks.	Tks. Saved.	Ckt. Mi. Saved	Gauge
Edgewater	435	349	86	26	22	9	1.25	0.70	4.72	19
Lake View	703	571	132	36	31	12	0.91	0.53	2.39	22
Lincoln	399	298	101	24	20	10	1.58	0.95	2.37	22
North	1004	846	158	48	42	13	0.91	0.49	1.12	[illegible]

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APPENDIX F. PLAN 10.

Call Circuit to Main Office "B" board. Call Circuit to West Pullman.

Mi.to W.Pull. or Relay	Total Calls B. H. through	Calls B. H. to	Total Trks. to	Ckt.Mi. W.Pull.	Mi. of Gauge	Mi. of Gauge

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APPENDIX F. CREDIT PLAN #9.

Over C.C.#1	Total Calls to Relay Pt.	Calls to Main or Wentwth.	Relayed Calls	Common Group Total Trks.	Separate Group Ww.or Main Trks.	Relay Trks.	W.Pull. Trks. Saved	Ckt. Mi. Saved	Gauge
Edgewater	435	349	86	26	22	9	1.25	0.70	4.72	19
Lake View	703	571	132	36	31	12	0.91	0.53	2.39	22
Lincoln	399	298	101	24	20	10	1.58	0.95	2.37	22
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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APPENDIX G: LOAD CARRIED BY RELAY OPERATOR.

PLAN 1: Load is 140 calls per busy hour.

The work of the relay operator is very much like that of an "A" operator with 100% trunking except for the fact that she gets her order over a call circuit instead of plugging in and answering. As the trunks end in plugs, team work is eliminated. This tends to reduce the load.

"A" opr's load, 100% trunking----------300 calls per busy hr.

From prob. curve, calls per max. 11

Working time per call, 120-11 $\frac{2 \text{ mins}}{\text{-------}}$ 10.9 seconds.

Increase due to no team work---------- 4

New working time per call ----------14.9

Calls per max.2' interval,120÷14.9 --- 8.06

Calls per busy hour (from curve)------140

PLAN 2: Load is 200 calls per busy hour.

As the incoming trunks are multipled in front of the relay operators and as the relay operators are arranged in teams of probably ten or more where a separate relay board is installed, there is no decrease in the "A" load due to loss of team work.

PLAN 3: Load is 130 calls per busy hour.

The details have been omitted as this plan has been condemned as too unsatisfactory from an operating and a service standpoint.

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PLAN 4: Load is 250 calls per busy hour.

The relay operator's load is practically that of a "B" operator with machine ringing trunks. It is assumed that there are four offices to a circuit. West Pull. "BB" operator handles 285 calls per busy hour which equals the load of an "A" operator with no trunking.

PLAN 5: Load is 200 calls per busy hour.

The relay operator's load is practically that of an "A" operator with 100% trunking.

PLAN 6: Load is 200 calls per busy hour.

PLAN 7:

No load figures are given on this plan as it has been condemned from an operating and a service standpoint without considering the cost.

PLAN 8: Direct trunks-no relay operators required.

PLAN 9: Load is 500 calls per busy hour.

The calls are relayed by the regular "B" operator at Main or Wentworth.

PLAN 10: Load is 200 calls per busy hour.

The work of the "B" operator on the relayed calls is practically that of an "A" operator with 100% trunking.

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APPENDIX H. PLAN 1.

		Relay Offices.	
	W.Pull.	Main	Wentwth.
Relay operators required (3 pos. section)		$\frac{128}{140}$ =.91	$\frac{125}{140}$= .89
"B" " (Appendix F., Plan 1)	2		

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APPENDIX H. PLAN 2.

	W.Pull.	Relay Offices. Main	Wentwth.
Relay operators required at		$\frac{128}{200}$ = .64	$\frac{125}{200}$ = .63
"B" " (Appendix F, plan 1)	2		

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APPENDIX H.

PLAN 4.

		Relay Offices.	
	W. Pull.	Main	Wentwth.
Relay Oprs. required		$\frac{128}{250} = .51$	$\frac{125}{250} = .50$
"BB" " " (App. F., Plan 4)	$\frac{650}{285} = 2.28$		

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APPENDIX H.

PLAN 6.

	W.Pull.	Relay Offices. Main	Wentwth.
Relay operators required		$\frac{128}{200}$ = .64	$\frac{125}{200}$ = .63

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APPENDIX H. - PLAN 8.

	W. Pull.	Main	Wentwth.
"B" operators required	3		
Multiple (subscribers)	3400		
[illegible]	£1,100.00		

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APPENDIX H.

PLAN 9

	Extra cost at "A" end W. Pullman	"B" Board. Main	Wentwth.
"B" operators required	2	$\frac{128}{500} = .26$	$\frac{125}{400} = .31$

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APPENDIX H

PLAN 9 (continued)

Summary of Total Costs.

	Initial.	Annual.
Cost of conductors	$31,757.00	$4,285.55
" at West Pullman	5,213.25	3,042.65
" " Main	678.62	395.72

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APPENDIX H.

PLAN 10

REGULAR "B" OPERATORS ACT AS RELAY OPERATORS.

	W.Pullman	Main	Wentwth.
Relay operators required	2	$\frac{128}{200} = .64$	$\frac{125}{200} = .63$
"B" " "	2		
Multiple (subscribers or trunk)	3400	5700+300	9600+200

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APPROVED.

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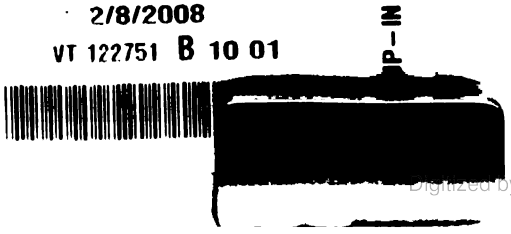

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